Investigation of Quality Control Measurements with Aging X-Ray Machines

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Original Research Article

ABSTRACT

The investigation of Quality Control measurement (QC) with ageing x-ray machines was undertaken. Ten x-ray machines were examined across different hospitals within Makurdi metropolis, Benue State using Gammex 330 kV meter and ten (10) X-ray Machines in government hospitals (GH) and private hospitals (PH) with age's (4-12) years for new X-ray Machines and (22-47) years for aged X-ray Machines. With these, on the quality of diagnostic X-rays and patient's dose were examined separately when a graph of age of the machine was plotted against the power n of the kVp and a graph of machines age was plotted against radiation intensity. Based on the analysis obtained in this study, the value of n for the new machines with ages (5-12) years has a value of 120 ± 2.73 and aged machines with ages (22-47) years has a value of 6.73 ± 16.11. This shows that there is a relationship between age and n. In conclusion, the findings of the present study showed that the output radiation dose of new and aged x-ray units differs at the same kVp and mAs measurements, indicating that the x-ray tube deteriorates as its ages increase, thereby posing higher health risk to patients and as such, the study recommends that QC measurement be undertaken on x-ray machines at definite stages of the machines life to verify the effects of aging of a machine on patient's dose.

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1. INTRODUCTION

Advancement in modern technology in recent times has led to a continuous increase in the number and availability of x-ray machines in both private and government-owned health facilities due to the benefits of x-ray diagnostic procedures [1]. Currently, there are far above 4000 x-ray machines in Nigeria some are new while others are used (known locally as *tokunbo*), out of which less than 5% are under regulatory control [2]. This fact thereby poses a great hazard and threat to patients, health personnel and also challenges to the regulatory body in Nigeria that is, Nigeria Nuclear Regulatory Authority (NNRA). The increase in the country has not been accompanied by a commensurable increase in qualified personnel in medical electronics, using service engineers from foreign suppliers to overcome this problem is not a viable option as the services are not available under short notice, and when available it is prohibitively expensive. Therefore, x-ray centers have continued to relay on the scarce services provided by the qualified local personnel in medical electronics. Maintenance and repair of medical equipment in Nigeria are further worsened by the general lack of service manuals, spare parts, and suitable environmental conditions in which to operate the equipment when repaired. This, coupled with a chronic shortage of financial resources to buy the new model of this expensive medical equipment, have exacerbated the problem by lowering the possibilities for follow-up actions based on the results of Quality Control (QC) measurements. To stress this view further, regulatory body like [1] insists that health facilities should not officially receive equipment until acceptance tests have been conducted by manufacturers/suppliers and proved that the required equipment specifications have complied with the latest national and international requirements and standards. The author in [3], recommended that the inclusion of a QC programme and maintenance contract in the tender specification before purchasing an x-ray machine is important; also it is an essential means of achieving accurate and timely diagnosis as well as optimizing equipment performance and patient dose. Though Radiographers agreed with the necessity and implementation of QC measurements, but they did not take responsibility for its implementation. Furthermore, the benefits of x-ray diagnosis are drastically undermined when the x-ray machine

is age and is operated without adequate QC measurement, the tests by the regulatory inspectors in Nigeria (NNRA) cannot be considered adequate as the tests are done for QC and for verification purposes and not how machine age affects the quality of diagnostic x-rays and patients' dose from x-ray examinations. Using a kV Meter to compare the radiation dose and radiation intensity from new and age x-ray machines is enough reason to draw attention on this issue [4,5].

Different studies exist in the literature on QC measurements. According to [6], while improvements on designs of X-ray machines and X-ray facilities have led to drastic reductions in personnel doses in the last decade, patients' doses within the same period actually increased and should radiographers always adhere to radiation protection/safety protocols in their daily practices, they could protect themselves and patients from deleterious effects of ionizing radiation. Regrettably, unwarranted exposures of patients to ionizing radiations due to foreseeable and often avoidable circumstances during diagnostic procedures have been reported [7]. Reasons adduced for this include poor knowledge of radiation protection and continued use of obsolete X-ray machines [6]. It is plausible to infer that patients may have been unnecessarily subjected to avoidable irradiation risks. The continued use of obsolete X-ray equipment seems to be a common problem with developing countries as [8] also reported the same scenario in Tanzania.

Moreover, protecting patients from unnecessary radiation exposure is not only the cardinal principle of radiation protection but also the behaviour of the imaging personnel and the condition of the imaging equipment [2]. Although the x-ray diagnostic procedures have revolutionized medical diagnosis and treatment of many diseases, their extensive use has raised concern on the possible overexposure [2,6]. A patient may receive a radiation dose in excess due to bad practice and bad equipment thereby drastically reducing the benefits of using high-quality x-ray imaging in diagnosing diseases and in the guidance of therapeutic procedures [1,3], hence every x-ray machine should be subjected to periodic quality control test. This polices and strategies are needed to ensure that the patient's received the lowest possible dose with maximum health benefits from x-ray examinations. For this reason, this study seeks to investigate QC

measurement with aging x-ray machines with the view of enhancing policies that will help curb the menace of the current practices across developing nations.

2. MATERIALS AND METHODS

The radiographic equipment used for this project work is X-ray machines and exposure to kV meter. The radiographic equipment information of five new and five aged X-ray machines from Government hospitals (GH) and private hospitals (PH) investigated. The year of installation of the X-ray equipment range from 15 years and above for aged X-ray machines and 1 to 12 years for new X-ray machines.

2.1 Parameter Estimation Procedures

The measurements procedures that were performed in this study are explained below step by step.

2.2 Determination of the Variation of Radiation Dose with the Power of the Kvp of New and Aged X-ray Machines

The radiographic measurements were performed using ten (10) x-ray units of a single phase in both government hospitals (GH) and private hospitals (PH). The reason for choosing these x-ray units is because of their ages. The kV meter was positioned in the central beam axis such that the x-ray tube source-to-image distance (SID) was 100cm for the measurements. The radiation field size was set to cover the kV meter to avoid the possible scatter radiation.

The x-ray unit was set at a stable 20 mAs why kVp was varied. An amount of useful x-ray beam was collimated to target the top of the instrument, an x-ray exposure was made and the kV reading was recorded. This step was repeated and measured radiation dose values were plotted against the corresponding kVp for each x-ray unit separately, equation of a straight line graph obtained from the graph was then compared with dose equation and machines age were plotted against power of the kVp to determine its variation as the ages of the machine.

2.3 Determination of the Variation of Radiation Intensity with New and Aged X-ray Machines

The kV meter was a position at 100cm (SID) from the focal spot of the x-ray tube. The exposures were performed with constant 80 kVp,

but with gradually increasing mAs of (5, 10, 20, 40 and 80). All measurements were repeated and the measured radiation dose values were plotted against the corresponding mAs for each x-ray unit separately, equation of a straight line graph obtained from the graph was then compared with dose equation and machines age were plotted against radiation intensity to determine its variation as the machine ages.

2.4 Determination of X-ray Tube Voltage Accuracy for New and Aged X-ray Machines

In this test, the kV meter was placed under the x-ray tube as mentioned above, both the dialed kVp (DkVp) and the measured kVp (MkVp) were noted and the percentage difference between the DkVp and the MkVp, were then calculated for each DkVp using the following equation:

$$\% \, Diff \, kVp = \frac{Tube \, Voltage \, Set - Tube \, Voltage \, measured}{tube \, Voltage \, measured} \, X \, 100 \quad (1)$$

The results for different x-ray units were tabulated, for any machine to pass this test the percentage difference between the DkVp and MkVp should be within ± 5% [7].

3. RESULTS AND DISCUSSION

To investigate radiation dose variation with the power of the kVp of new and aged x-ray machines, the x-ray unit was set at a stable 20 mAs why kVp was varied. An amount of useful x-ray beam was collimated to target the top of the instrument, an x-ray exposure was made and the kV reading was recorded. This step was repeated and measured radiation dose values were plotted against the corresponding kVp for each x-ray unit separately as shown in appendix ii, equation of a straight graph obtained from the graph was then compared with dose equation and machines age were plotted against power of the kVp to determine its variation as the ages of the machine.

To determine the variation of Radiation Intensity *µGy/mAs* with ages of a machine using new and aged x-ray machines, the exposure was performed with constant 80 kVp, but with gradually increasing mAs of (5, 10, 20, 40 and 80). All measurements were repeated and the measured radiation dose values were recorded and plotted against the corresponding mAs for each x-ray unit separately as detailed. Equation of a straight line graph obtained from the graph was then compared with dose equation and

machines age were plotted against radiation intensity to determine its variation as the ages of the machine. Thus, the effects of ageing of the machine on the quality of diagnostic x-rays and patient's dose were examined separately when a graph of age of the machine was plotted against the power n of the kVp and a graph of machine age was plotted against radiation intensity as shown in Figs. 1-4 respectively. Base on the analysis obtained in this study, it is worthy to note that the power n of the kVp increases as the age of the machine increases; and radiation intensity *µGy/mAs* of aged x-ray machines increases more than the new machines at the same clinical examination as the age of the machines increases; this proven parameter shows that aged machines produce high energy emission spectrum more than the desired kVp set which is detrimental to patients health and against the principle of ALARA as stipulated by [9]. By this implication, patients using this machine will receive a higher radiation dose because of the amount of radiation quantity produce by it. This is often caused by lack of quality control, inadequate x-ray tube maintenance and tube age and anode surface damage thereby posing a higher health risk to patients using this machine.
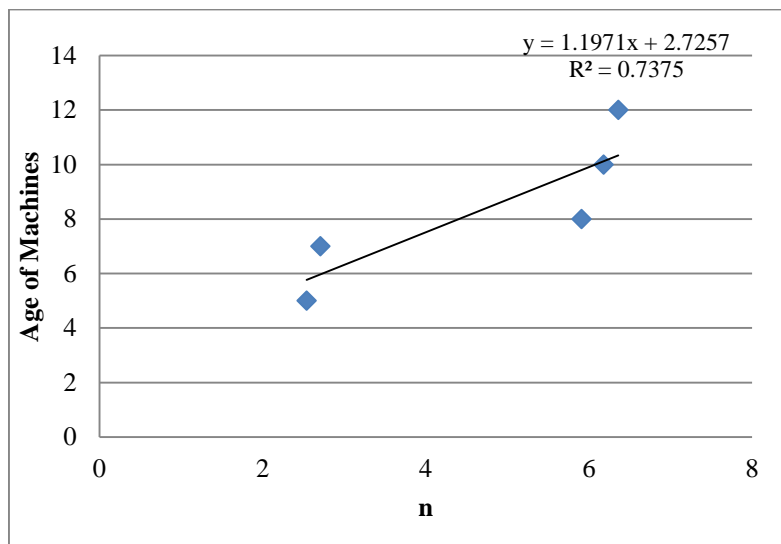

$$y = 1.1971x + 2.7257$$
$$R^2 = 0.7375$$

Fig. 1. Graph of Age of Machines versus power n for New X-ray Machines

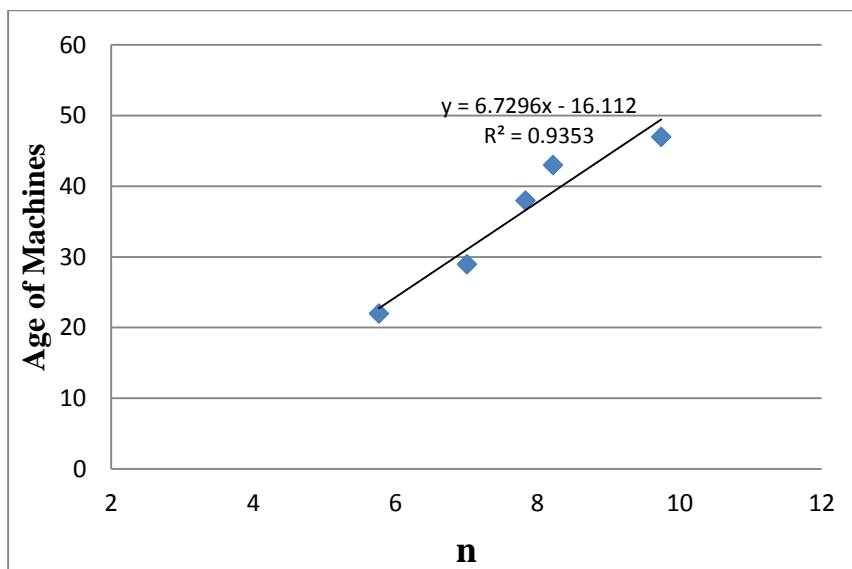$$y = 6.7296x - 16.112$$
$$R^2 = 0.9353$$

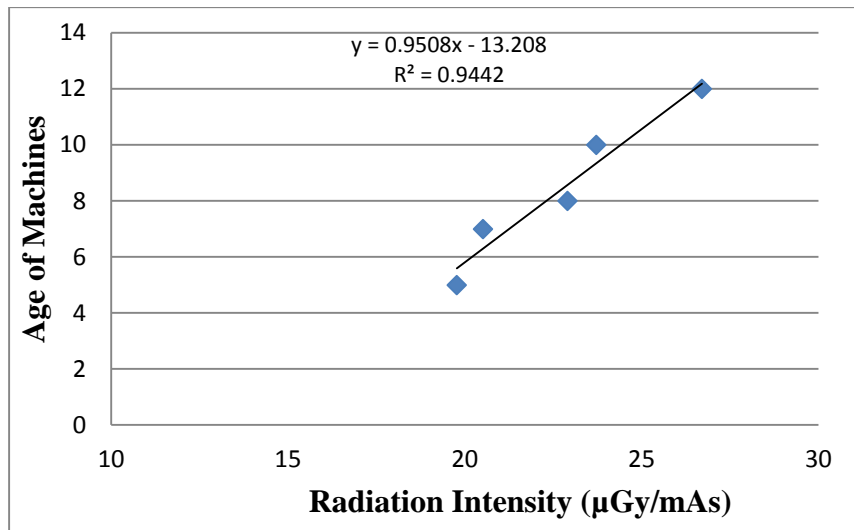**Fig. 2. Graph of Age of Machines versus power n for Aged X-ray Machines**

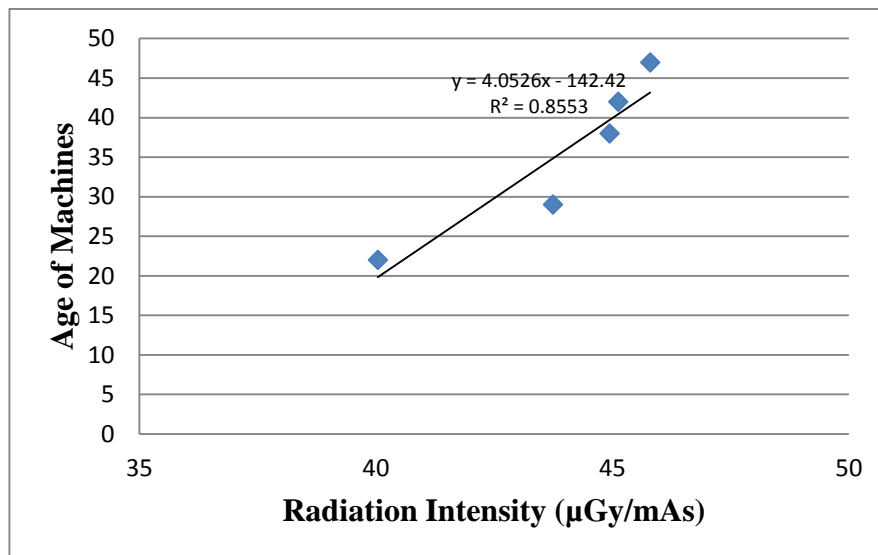**Fig. 3. Graph of Age of Machines versus Radiation Intensity (μGy/mAs) for New X-ray machines**

Fig. 4. Graph of Age of Machines versus Radiation Intensity (μGy/mAs) for Aged X-ray machines

4. CONCLUSION

The investigation of QC measurement with ageing x-ray machines is presented. Ten x-ray Machines were examined this study with the purpose of safety and dose optimization. The optimal radiation dose for optimal image quality can be achieved by understanding the parameters that affect radiation dose and image quality, this consist of QC programs to test radiographic devices periodically especially when they are aged. Based on the analysis obtained in this study, it is worthy to note that the output radiation dose of new and aged x-ray units differs at the same kVp and mAs measurements, indicating that the x-ray tube deteriorates as its ages increase, thereby posing a higher health risk to patients.

The study further shows that a substantial dose reduction could be achieved using new x-ray units; additionally, if both government and private x-ray centers have realized the appraisal of QC program, maintenance costs, contract service of maintenance program to perform minor repairs, substantial dose reduction could be achieved. Based on the findings of the present study, the study recommends that work should be repeated

with x-ray machines that have accurate records of used factor and workload in order to determine the effects of workload on the aging of the machine. Also, further work should be done on x-ray machines at definite stages of the machines life in order to verify the effects of aging of a machine on patient's dose.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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